An Analysis of the Technical Performance Demands of Elite Female Boxers.

by

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Abstract

The aim of this study was to analyse the technical performance demands of elite level female boxing across four different bout outcomes (unanimous win, split win, split loss and unanimous loss). 37 bouts (74 performances) were analysed from the quarter-finals, semi-finals and finals of the 2014 women's world championships. The analysis was conducted using key performance indicators (KPI's), including total punches, types of punch, punch outcome, type of defence and type of exchange. Unanimous winners threw the most punches overall and also in each round independently. Unanimous win and split win were found to throw significantly more very successful punches and successful three punch combinations than both split loss and unanimous loss. The number of exchanges initiated was highest for unanimous win, followed by split win, with unanimous loss initiating the least number of attacks. Although there was no significant difference between unanimous win and split win, the main differences were found to be very successful punches, successful punches, efficiency and individual attacks. The differences between most KPI's was smaller between split win and split loss than unanimous win and unanimous loss. Split winners initiated more exchanges in order to dominate bouts. This study provides a detailed analysis of KPI's across four different bout outcomes (unanimous win, split win, split loss and unanimous loss) and can be used by coaches and athletes in order to assist in the planning of training programmes and informing tactics.

No portion of the work referred to in this Research Project has been submitted in support of an application for another degree or qualification of this, or any other University or institute of learning.

The project was supervised by a member of academic staff, but is essentially the work of the author.

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Introduction

Women's boxing has been a sport with increasing numbers participating in England over the past decade. Figures announced by England Boxing (2013) show an increase in the number of registered female boxers in Great Britain has risen from 70 in 2005 to more than 1000 in 2011, with these figures increasing further after the 2012 London Summer Olympics. Figures published in 2013 by Sport England's 'Active People Survey 7', show a 51% increase in once-a-week participation in the year after the Olympics for women's boxing, with 23,300 taking part between October 2011 and October 2012 and 35,100 people participating between April 2012 and April 2013. The inclusion of women's boxing in the 2012 London Summer Olympic allowed a worldwide audience to watch the sport for the first time. The increase in participation in the U.K. may be a reflection on the success of Nicola Adams who became the first woman to win an Olympic gold medal in boxing.

Understanding the demands of a sport has become a key tool to improve performance, increasingly more so with the emergence of performance analysis (Hughes & Bartlett, 2002). Bloomfield, Polman and O'Donoghue (2007) state that the management of the physical and physiological status of elite soccer players relies on detailed knowledge of the performance demands. This theory applies to many other sports, such as badminton, rugby and Australian rules football, in which studies have looked at different technical and physical demands - such as intensity of exercise, speed measures, ball catches, ball touches and tackles - in order to gain a better understanding of what is required for successful performances (Faude et al., 2007; Catterick, Knowles, Sirotic & Coutts, 2009; Johnston et al., 2011).

Whilst there has been extensive research in team sports, individual sports have typically received less attention. One sport in particular is boxing, more specifically women's boxing, where the research is very limited. The earlier studies touching on the demands of boxing were from physiology papers (Smith et al., 2001; Smith, 2006), in which the demands of a bout were analysed in order to replicate a bout for physiological assessment. Smith et al. (2001) analysed bouts from the 1994 Commonwealth Games and found that on average 112 punches were thrown per 3 minute round, this is in line with Smith (2006) who developed a simulation protocol using a boxing dynamometer aiming to replicate the sport's physiological demands.

More recently a study by Kapo, Kajmovic, Cutuk, and Berisa (2008) looked in greater depth at the demands of 40 bouts (80 performances) from the 15th Bosnia and Herzegovina Individual Boxing Championships, looking at punch type, frequency and type of defence. The finding state that out of all punches thrown 48.2% were straight/direct punches, 48.1% were hook punches and 3.7% were uppercut punches, of these the majority of punches were using the lead hand (57.2%). Comparing the lead hand and the rear hand Kapo et al. (2008) found that 31.3% of punches performed were lead hand direct/straight and 25.2% were lead hand hook punches, this differs from the rear hand where 16.9% of punches performed were rear hand straight/direct compared to 23% of punches being rear hooks. This insight into the demands of boxing provided a platform for further research, but due to grouping all performances together the study lacks information on the outcome of the bouts analysed, therefore cannot be used in a practical environment to improve performance due to the lack of information on winning and losing performances.

El-Ashker (2011) conducted a study into the demands of male boxers, taking performance outcome into account. The study consisted of 66 participants from a national boxing competition. El-Ashker (2011) also used lead hand and rear hand for straight punches, hook punches and uppercut punches, but split them into rounds oppose to the overall bout (Kapo et al., 2008), concluding that winners threw more punches in all three rounds than losers, with the differences being significant in rounds two and three. Another difference between the performances of winners and losers was combinations thrown (El-Ashker, 2011), with winners throwing more punch combinations in order to score points and or make an impression on judges, concluding that three or more punch combinations were most likely to score, despite two punch combinations being the most frequent. Despite the results of this research highlighting key features of amateur boxing, there are many presumptions and unjustified statements which may not be completely accurate, such as 'Data showed that boxing matches were extremely energetic' and 'winners are faster and are able to keep opponent at range' (El-Ashker, 2011, p. 362). These statements are unjustified as there is no measure of energy or speed within the study.

A 2013 study by Davis, Wittekind and Beneke also looked at the activity profiles of winners and losers in novice-level amateur boxing, using similar key performance indicators (KPI's) to El-Ashker (2011), including type of punch, punch success, punch combinations and defence type for winners and losers across rounds. The study concluded that a key factor in winning a bout was the ability to maintain a high frequency of attacking movements, specifically using straight punches to the head with the lead-hand and punch combinations as these are most likely to be scored by the judges. Davis et al. (2013) agrees with

El-Ashker (2011) with regards to punch combinations, finding that triple-punch combination had the highest probability of being scored, regardless of punches landed. Davis et al. (2013) also suggests that there is no difference in the total numbers of defensive movements between winners and losers, however a winning boxer uses defensive movements to initiate a counterattack.

Although Davis et al. (2013) built upon and potentially improved the analysis of El-Ashker (2011) there are several similar limitations of the two papers. The reliability of the results in both papers are questionable, with Davis et al. (2013) stating that 5 bouts were analysed twice by the same coach, but failing to report the method of checking for consistency and the results of those tests, also no mention of testing for inter-reliability. El-Ashker (2011) reported the results of the reliability tests conducted, but only tested three KPI's for reliability and the method used to test for reliability only takes into account overall statistics oppose to testing over a time-based analysis, with the inclusion of proportion of agreement (Cooper, Hughes, O'Donoghue & Nevill, 2007), suggested to be a better way of testing for reliability. Both studies compare the results of winners and losers, but the outcome of the bouts were based on the punches landed (Davies et al., 2013) and the scoring punches landed (El-Ashker, 2011); these were counted during the analysis of the fights rather than the judges' decision. Therefore some of the outcomes that are suggested as important when winning a bout may be based on data that has come from a boxer who in fact lost the fight. This method of defining winners and losers may have been more applicable to the old scoring system in which a bout was scored by how many punches a boxer landed in a scoring zone, with judges awarding points for successfully landed punches and the boxer with the most points at the end of the bout winning. Due to a 2014 rule change amateur

boxing now uses a 10 point scoring system with judges awarding merit when scoring a round based upon the number of quality blows on target area, domination of the bout by technical and tactical superiority, competitiveness and infringement of the rules (AIBA, 2014). The new scoring system means that a judge gives the boxer they thought won the round 10 points and the boxer who lost the round between 9 and 6, depending on how close they thought the round was, using the criteria previously mentioned. Hence the data collected from all studies to-date may not be give an accurate reflection on the demands of winning a boxing match, with no studies analysing bouts that were decided using the new scoring system.

A later paper by Davis, Benson, Pitty, Connorton and Waldock (2014) built upon previous research and conducted a study looking at the 'activity profile of elite male amateur boxers'. The main finding show that for attacking movements there is no significant difference between winners and losers in round one and only rear hand hook landed being significant in round two. Round three found significant differences between winners and losers for total punches landed, lead hand hook landed and rear hand hook landed, with the study concluding the importance of punch accuracy oppose to throwing a high frequency of straight punches. A further conclusion was that regardless of winning or losing the activity profile represented an "inverted U" with many parameters increasing between round one and round two and decreasing between round two and round three, whist having the ability to perform 1.4 actions per second throughout the bout.

Although previous research has highlighted the key performance demands of boxing, they do not reflect the contest format of female boxing with regards to the number of rounds or round length. Women compete over 4

rounds lasting 2 minutes each compared to men who compete over 3 rounds of 3 minutes. There has been limited boxing studies for bouts with 4 x 2 minute rounds. Smith, Dyson, Hale and Janaway (2000) and Ghosh (2010) both in part looks at and includes details on 4 x 2 minute rounds, although these two papers investigate biomechanical and physiological elements of boxing respectively, rather than performance demands. Most current literature is based on 3 x 3-minute rounds (El-Ashker, 2011; Davis, 2014a) or 3 x 2-minute rounds (Davis, 2013; Davis, 2014b), this lack of research for 4 x 2-minute rounds may be due to regular changes in the sport's rules, round and bout length (Davis et al., 2013).

The only study to the researcher's knowledge that looks into the demands of female boxing over 4 x 2-minute rounds is Davis, Benson, Waldock and Connorton (2015) who compare the performance demands of the winners and losers of 18 Olympic bouts. It was reported that there were significant differences between winners and losers for straight rear hand punches, uppercut punches, body punches and defensive foot movements in at least one of the four rounds. Winners threw more punches in all 4 rounds and also had a better total attack- punches landed ratio, providing the first insight to the performance demands of female boxing. It is also suggested that women have a higher action rate than men despite performing less attacking movements, with women performing more vertical hip movements, showing that the comparison across genders cannot be made. This study (Davis et al., 2015) also uses the old scoring system, so despite the first results having been reported on women's boxing, it is unclear whether these performance demands apply to the new scoring system, due to possible changes in both the technical and tactical approaches going into a bout. The paper by Davis et al.(2015) also

lacks information on how the analysis was tested for reliability and the results of those tests, therefore the data provided may not be reliable and would not be of use when informing the demands of female boxing.

Research has been carried out looking at the differences between genders for other combat sports. Meaningful differences were found between skilled male and female Tae Kwon Do participants (Heller et al., 1998; Toskovic, Blessing & Williford, 2004), suggesting that a difference in performance styles or tactics is likely. Thus male and female practitioners may be dependent on different demands in order to implement a successful performance. Therefore performance demands cannot necessarily be transferred across genders and some research should be conducted concentrating solely on female sport.

All studies looking into the performance demands of boxing to-date have only split the sample into winners and losers, whereas the Amateur International Boxing Association (AIBA) state that a winner will be appointed by either a unanimous decision or split decision (AIBA, 2015). This results in there being four possible outcomes to a bout, a unanimous win, a split win, a split loss and a unanimous loss. Therefore there may be large differences between winning performances that have previously been grouped together, likewise with losing performances. Gaining a greater understanding of the differences in performance between such outcomes could be beneficial in the coaching and development of boxers, both technically and tactically.

Due to the lack of research looking into the demands of women's boxing, the limitations of the studies that have been published, the emergence of a new scoring system and the length of bouts differing between studies, it is important that more research is to be done in the area of women's boxing. Therefore, this

study analysed the performance demands of elite amateur female boxing, focusing on what differentiates between a unanimous win, split win, split loss and unanimous loss, through the analysis of key technical performance indicators.

Method

Participants

Thirty-seven bouts (74 performances) from the AIBA Women's Boxing World Championships 2014 were analysed, 10 quarter finals, 17 semi-finals and 10 finals, each containing two elite female boxers. All bouts consisted of 4 rounds lasting 2 minutes each, with a 1 minute break between each round. The footage used was provided by GB Boxing (Appendix 1). The bouts used ranged across all 10 weight categories (48kg (2 bouts), 51kg (7 bouts), 54kg (3 bouts), 57kg (3 bouts), 60kg (5 bouts), 64kg (3 bouts), 69kg (2 bouts), 75kg (7 bouts), 81kg (3 bouts) and +81kg (3 bouts)). The sample of bouts analysed is based on previous research, using more performances to ensure a sufficient sample was used. Previous research have used between 32 and 66 performances (El-Ashker, 2011; Davis et al., 2014; Davis et al., 2015 & Davis et al., 2015).

Procedures

Ethical approval to conduct the study was granted by the faculty of applied and health sciences research ethics committee at the University of Chester (Appendix 2). The boxers were split into winners and losers, then further into four groups dependent on the judges' decision from the championships, which

were unanimous win, split win, split loss and unanimous loss. A unanimous decision occurred when the three judges appointed the same winner. A split decision occurred when two judges appointed the same winner and the third judge appointed the opposing boxer as the winner or a draw between the two boxers. The analysis was conducted using a boxing specific template, on Dartfish Software (Dartfish Inc, Fribourg Switzerland), where the bouts were coded for KPI's. All KPI's will be coded based on definitions from previous research (Thomson, Lamb & Nicholas, 2013) (appendix 3). Once the bouts had been coded the data was exported from Dartfish (Dartfish Inc, Fribourg Switzerland), into Microsoft Excel (Microsoft Corperation, Washington, United States). The KPI's and variables used have been selected according to the criteria that the judges use for deciding the winner of a bout and from previous research also (El-Ashker, 2011; Davis et al., 2014; Davis et al., 2015 & Davis et al., 2015).

The criteria consists of; the number of quality blows on target, domination of the bout, competitiveness, technique and tactical superiority and infringement of the rules (AIBA, 2014).

The round, punch type, success of punch, type of defence, number of punches, outcome of attack along with which boxer initiates the attack will all be coded for both winners and losers. The analysis of the data derived from the coding was a direct comparisons between both 'winner and loser' to detect which KPI's are important to winning a bout.

Reliability

Two observers coded the same round for inter-observer reliability. Intra-observer reliability was also tested, with the observer coding the same round two weeks apart. The approach taken to test the reliability of the data was that of Cooper et al., (2007). The frequency of each performance indicator over 12, 10-second periods were inserted into time cells for both test and retest. The percentage of agreement and the percentage of agreement with the allowance of plus or minus one were calculated with corresponding confidence intervals. A median sign test was used to test for significant differences for all performance indicators using a P-value of $P<0.05$.

Table 1. Inter-reliability for punch type data

		Percentiles					
Performance Indicator	Median (sign test P)	2.50%	97.50%	PA=0 (%)	Confidence Interval (%)	PA ± 1 (%)	Confidence Interval (%)
Total Punches	0 (1)	-3	3.725	25	0.5 to 49.5	41.7	13.7 to 69.6
Jab	1.5 (0.549)	-1.725	3	8.3	0 to 24.0	41.7	13.7 to 69.7
Backhand	0 (1)	-2.725	2.725	33.3	6.7 to 60.0	66.7	40.0 to 93.3
Leadhook	0 (0.727)	-2	2.45	33.3	6.7 to 60.0	75	50.5 to 99.5
Rearhook	-0.5 (1)	-1.725	2	8.3	0 to 24.0	75	50.5 to 99.5

Table 1 shows the format in which reliability was presented. See appendix 4 for full inter and intra reliability results. Neither inter or intra reliability showed any significant differences between analysis of any KPI's, although percentage of agreement was as low as 8.3% for the inter-reliability of four performance indicators. For Intra-reliability unsuccessful miss had the lowest percentage of agreement, at 50%.

Statistical Testing

All data was tested for normality using the Kolmogorov-Smirnov test. Statistical tests were used to test for significance between unanimous win, split win, split loss and unanimous loss for all variables proposed (types of punches, types of defence, success of each punch and number of punches). Due to the data not being normally distributed, non-parametric tests were used. To test between unanimous win, split win, split loss and unanimous loss firstly a Kruskal-Wallis test was performed on each variable and then followed up by a set of Mann-Whitney U tests between groups when significant differences were found. For all statistics the significance level was set at $P<0.05$. All statistical tests were performed using SPSS (IBM, New York, United States).

Results

Table 2 shows unanimous winners on average threw the most punches in a bout (171.7), with unanimous losers throwing the least (148.2). Boxers winning a bout on a split decision on average threw more punches (156.1) than those losing a bout on a split decision (153.6). Unanimous winners threw the most punches in round 2 (46.0), split winners in round 1 (42.7) and both split losers (39.8) and unanimous losers (38.4) performed the most punches in round 3. All four bout outcomes threw the least punches in the last round.

The number of very successful punches landed by unanimous winners was significantly higher than split losers (P=.002) and unanimous losers (P=.001). Split winners also executed significantly more very successful punches than split losers (P=.037) and unanimous losers (P=.016). The punch outcomes, successful punches, unsuccessful hits and unsuccessful defended

were all highest for unanimous winners, with split losers performing the most punches resulting in a unsuccessful miss.

Unanimous winners had the best punch efficiency (0.33), with unanimous losers having the worst (0.28). Split winners and split losers had the same punch efficiency (0.31).

Table 2. Number of punches and punch outcomes across all four bout outcomes (Mean ± SD).

Performance Indicator	Unanimous Win	Split Win	Split Loss	Unanimous Loss
Total punches	171.7± 51.3	156.1 ± 47.1	153.6 ± 38.2	148.2 ± 31.2
Number of punches- Round 1	43.9 ± 14.3	42.7 ± 14.7	38.2 ± 12.7	36.7 ± 10.4
Number of punches- Round 2	46.0 ± 17.6	38.9 ± 13.4	39.5 ± 13.4	37.9 ± 12.4
Number of punches- Round 3	42.3 ± 13.5	38.1 ± 12.7	39.8 ± 14.1	38.4 ± 8.1
Number of punches- Round 4	39.4 ± 13.6	35.5 ± 12.2	35.6 ± 11.2	35.1 ± 9.3
Very successful punches	6.4 ± 3.1[xy]	5.6 ± 3.4[xy]	3.4± 2.8	3.1 ± 2.4
Successful punches	51.6 ± 21.1	43.9 ± 16.2	44.3 ± 19.5	38.2 ± 17.5
Unsuccessful hits	23.4 ± 17.7	20.2 ± 9.4	21.4 ± 11.6	22.0 ± 11.8
Unsuccessful defended	41.3 ± 16.6	36.9 ± 19.9	32.9 ± 20.3	38.1 ± 15.0
Unsuccessful miss	49.0 ± 13.8	50.3 ± 14.0	51.6 ± 18.0	46.8 ± 10.2
Very successful and successful punches	58.0 ± 22.8	49.5 ± 17.8	47.7 ± 20.8	41.3 ± 18.3
Efficiency	0.33 ± 0.08	0.31 ± 0.08	0.31 ± 0.09	0.28 ± 0.09

[x] Significantly different to split loss [y] Significantly different to unanimous loss

Split winners threw the highest number of jabs and backhands (table 3), in comparison unanimous losers threw the least. Split losers threw more backhands than unanimous winners, although of all outcomes unanimous winners threw the most lead hooks, rear hooks and power punches. Surprisingly in bouts lost unanimously boxers threw the second highest number of lead hooks, rear hooks and power punches when compared to unanimous win, split win and split loss.

The percentage of very successful and successful punches landed was lowest in unanimous losers for all punch types (jab, backhand, lead hook, rear hook and power punches), with jab being the least successful at 22.2%. Losers via a split decision landed the highest percentage of successful and very successful jabs (29.4%) and lead hooks (34.4%). Unanimous winners boast the highest percentage of very successful and successful backhands (36.6%) and power punches (36.1%). The backhand was the unanimous winners most successful type of punch (36.6%), whereas split winners, split losers and unanimous losers type of punch with the highest percentage of very successful and successful punches landed was the rear hook.

Table 3. Number of punches and percentage of very successful punches across all four bout outcomes (Mean ± SD).

Performance Indicator	Unanimous Win	Split Win	Split Loss	Unanimous Loss
Jab	55.5 ± 29.8	59.1 ± 18.4	52.1 ± 22.4	45.1 ± 21.2
Back hand	49.9 ± 22.0	50.9 ± 16.0	50.1 ± 18.0	43.0 ± 13.9
Lead hook	37.8 ± 22.4	24.6 ± 20.8	27.1 ± 14.3	32.5 ± 15.9
Rear hook	25.1 ± 15.9	19.8 ± 15.6	22.4 ± 21.6	25.0 ± 17.7
Power punches	116.2 ± 40.9	97.0 ± 39.9	101.6 ± 33.1	103.1 ± 27.9
Jab percentage very successful and successful (%)	26.1 ± 10.3	27.5 ± 10.2	29.4 ± 11.7	22.2 ± 9.1
Backhand percentage very successful and successful (%)	36.6 ± 10.0	32.1 ± 9.2	29.7 ± 13.2	25.9 ± 10.7
Lead hook percentage very successful and successful (%)	33.5 ± 12.3	33.6 ± 15.3	34.3 ± 15.1	29.8 ± 15.3
Rear hook percentage very successful and successful (%)	35.9 ± 18.8	37.9 ± 23.7	35.5 ± 22.3	35.0 14.5
Power punch percentage very successful and successful (%)	36.1 ± 9.6	34.5 ± 7.8	31.7 ± 9.2	29.8 ± 9.6

As shown in table 4, unanimous winners performed the most of every punch combination successfully, with unanimous losers performing the least in all five combinations. Two punch combinations were the most frequent for all

four bout outcomes. Unanimous winners and split winners successfully landed significantly more three punch combinations (*P*=.012 and *P*=.026 respectively) when compared to unanimous losers. Four punch combinations were significantly higher for unanimous winners (*P*=.021), split winners (*P*=.033) and split losers (*P*=.035) when compared to unanimous losers.

Table 4. Successful punch combinations across all four bout outcomes (Mean ± SD).

Punch Combination	Unanimous Win	Split Win	Split Loss	Unanimous Loss
Single punch	5.8 ± 4.8	3.8 ± 3.4	4.0 ± 2.6	2.3 ± 2.6
Two punches	7.9 ± 5.6	7.5 ± 4.3	6.3 ± 4.6	5.6 ± 3.5
Three punches	5.3 ± 2.9ɣ	4.8 ± 2.9ɣ	4.0 ± 2.3	3.1 ± 2.4
Four punches	2.9 ± 2.4ɣ	2.4 ± 2.4ɣ	2.2 ± 1.4ɣ	1.3 ± 1.6
Five or more punches	2.9 ± 3.6	1.7 ± 3.6	2.0 ± 1.8	1.3 ± 1.7

ɣ Significantly different to unanimous loss

As seen in table 5 bouts lost unanimously performed significantly more arm defence movements than unanimous winners (*P*=.005), split winners (*P*=.034) and split losers (*P*=.034). Unanimous winners performed the most foot and trunk defence movements. Split winners performed the least number of trunk defence movements, with unanimous losers performing the least number of foot defence movements.

Table 5.Number of successful defensive actions across all four outcomes (Mean ± SD)..

Defence Type	Unanimous Win	Split Win	Split Loss	Unanimous Loss
Arm	7.6 ± 7.9ɣ	7.9 ± 5.4ɣ	7.9 ± 5.5ɣ	16.3 ± 12.6
Trunk	13.0 ± 11.1	9.1 ± 7.7	11.6 ± 5.5	9.2 ± 5.5
Foot	16.0 ± 9.8	13.8 ± 9.1	14.4 14.2	13.4 ± 9.8

ɣ Significantly different to unanimous loss

As shown in figure 1 unanimous win carried out the most individual attacks per bout (9.3) and split win the least (3.9). Unanimous win also initiated the most exchanges (32.8), with split win with the second most (29.8), followed by split loss (23.6) and lastly unanimous loss with 21.7.

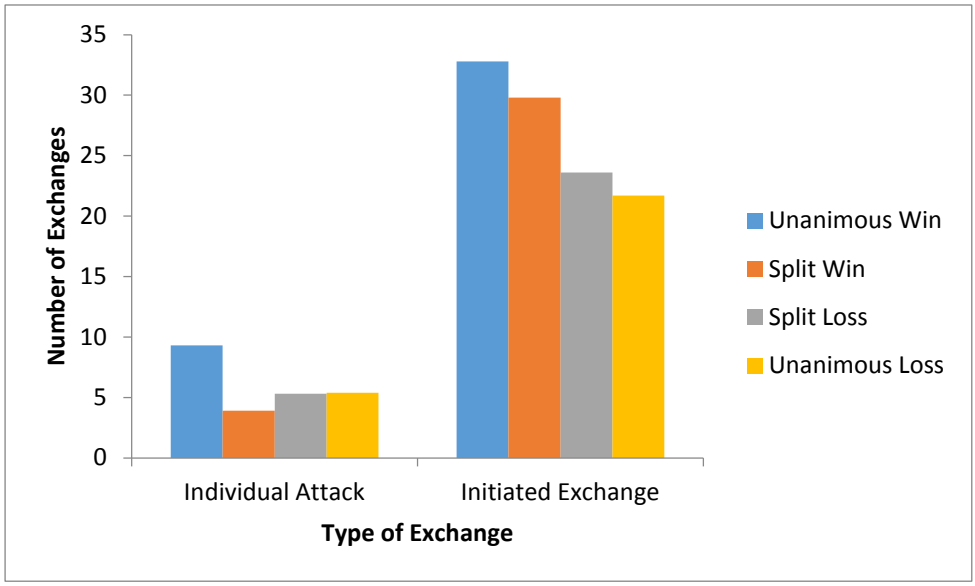

Figure 1. Individual attack and initiated attack across all four bout outcomes (Mean).

Discussion

This study concentrates solely on the technical performance demands of elite level female boxing, with the aim of informing the differences in performance, not only between winning and losing, but between a unanimous win, split win, split loss and unanimous loss.

Results show that there are clear differences in performance demands between all four bout outcomes for many of the performance indicators used. Boxers winning with a unanimous decision throw the most punches in all four rounds (table 1) and therefore overall, which is in line with previous research including Davis et al. (2015) study into female boxing. Interestingly differences between a split win and a split loss are marginal as split loss threw more punches in rounds 2,3 and 4, with differences of 0.6, 1.7 and 0.1 respectively The biggest difference came in the first round where split win on average threw 4.5 more punches than split loss, suggesting a possible importance to the first round. For all four bout outcomes the lowest number of punches thrown in a round was round 4. El-Ashker (2011) suggests that the reduction in punches in the last round was due to fatigue, particularly in losers, but in contrast the results of this study show that the reduced number of punches thrown in the last round is greater in unanimous and split winners than in split losers and unanimous losers compared to the first round. This inconsistency between studies could be down to differences in the standard of the subjects involved, with the participants in the El-Ashker (2011) study being sub-elite.

A key finding from the results shows unanimous winners throw significantly more very successful punches than split losers and unanimous losers, as do split winners. This gives a clear difference between winners and

losers, with only a difference of 0.8 between unanimous winners and split winners and a difference of 0.3 between split losers and unanimous losers. The importance of this significant difference for very successful punches between split winners and split losers is emphasized by how close the successful punches performance indicator is between the two outcomes. Split losers on average landing more successful punches despite losing the bout, landing 44.3 compared to split winners 43.9. Due to previous studies (El-Ashker, 2011; Davis et al., 2013; Davis et al., 2014 & Davis et al., 2015) grouping all winners in a group and all losers in a group there are similarities with past research when comparing unanimous wins and unanimous losses- with previous research finding differences between successful or landed punches between winners and losers- but differences to previous studies when compared to split wins and split losses. Similarly with efficiency the difference between unanimous win and unanimous loss backs up the findings of Davis et al. (2015), who report that the ratio of punches thrown to punches landed is lower for winners in all 4 rounds, but building upon these findings this study shows that there is no difference in efficiency between a split win and a split loss, with both outcomes having an efficiency of 0.33.

The differences between punch types show differences between all four weight outcomes. Although unanimous win has the lowest percentage of backhands thrown to overall punches, they have both the highest percentage of 'very successful and successful' backhand punches and power punches thrown, whereas surprisingly split loss have the highest percentage very successful and successful jabs and lead hooks. The results show that landing successful rear hand punches is important in winning a bout, due to both unanimous win and split win have a greater success percentage for rear hand punches than split

loss and unanimous loss. These results differ from those reported in previous research with Davis et al. (2013) stating the importance of landing lead hooks and El- Ashker (2011) writing that the higher frequency of every punch type occurs with winners, particularly the straight lead hand, although these variations may have occurred due to differences in gender and the standard of boxers in the two studies not being of an elite level.

Punch combinations have previously been reported as a key factor in winning a bout, with two punch combinations being most frequent and triple punch combinations being most likely to score (El- Ashker, 2011; Davis et al., 2013). The results of this study add depth to those reports, with agreement that two punch combinations are the most frequent and also the most successful across all four bout outcomes, but a main difference between winning and losing appears to be with three and four punch combinations. Unanimous win and split win were found to have a significantly higher amount of successful three punch combinations than unanimous loss, whilst unanimous loss also had a significantly lower number of successful four punch combinations than unanimous win, split win and split loss. Split loss performed more successful single punch and five or more punch combinations than split win, highlighting that although the margins are smaller between split decision performances two, three and four punch combinations are crucial to a winning performance.

Along with the differences within attacking parameters, there were also differences between defensive performance indicators. Bouts lost unanimously were found to perform significantly more arm defences than unanimous win, split win and split loss, suggesting that past research (El-Ashker, 2011; Davis et al., 2015) is correct in highlighting the importance of movement and that maybe tactically evading the punch is more effective than blocking it. Unanimous

winners perform more trunk and foot defence movements, whether this is due to tactics or greater mobility is unclear, but is consistent with the defensive data that has already been reported already with Davis et al. (2015) finding that 10.5 defensive foot actions per round for winners compared to 6.9 for losers.

Due to the changes in scoring system mentioned previously the number of exchanges initiated and number of individual attacks are an important factor and may have an effect on the decision a judge makes. Unanimous win initiated the most exchanges and also had the most individual attacks, therefore may be seen by the judge as increased domination of the bout and competitiveness, which are both criteria on the AIBA scoring system (AIBA, 2015) and therefore having an increased chance of winning the round. For bouts decided by split decision this criteria gives a possible explanation for the final outcome of the bouts, given the marginal differences in the performance indicators throughout, with split winners initiating on average 6.2 (or 26%) more exchanges a bout. Due to the change in scoring system there is no research looking into domination and competitiveness of bouts, but it is something that needs including in future research.

Despite this study analysing bouts after the change in scoring system, there has since been a minor change to the criteria as of February 2015, combining 'domination of the Bout' and 'technical and tactical superiority' to form 'domination of the Bout by technical and tactical superiority'. Therefore this may change tactics and consequently change performance demands, potentially stopping boxers going into a bout with the aim of dominating by solely throwing a high number of punches. This is a limitation to the study as it is unclear whether the performance demands reported will be the same as the

performance demands of bouts using the most recent scoring criteria. To enable this comparison a further study would need to be conducted.

Another limitation of the study was that at times the analysts view of the boxers was impaired by either the referee, the opponent or the boxer having their back to the camera. This caused difficulties in analysing KPI's where this occurred, particularly punch outcome, possibly explaining in-part why some KPI's had a lower percentage of agreement. An additional limitation of the study is the analysis of the bouts was conducted by somebody whom has never worked within boxing or has no previous experience as a boxer or coach, therefore knowledge of the sport could have been greater. This may also be a factor when looking at reliability, although all analysis was conducted using a clear set of definitions to ensure the analysis was correct.

This study has provided a detailed breakdown into the technical and physical demands of elite female boxing, comparing unanimous win, split win, split loss and unanimous loss, through the analysis of KPI's. The results found that unanimous winners threw the most punches of all four rounds and performed more very successful and successful performance. Many of the differences in performance demands between split win and split loss were marginal, but the key differences found split winners performed significantly more very successful punches, more successful 2 and 3 punch combinations and initiated more exchanges. Using these results and understanding the differences between the performance demands of different bout outcomes will help to inform tactics through the greater understanding of which KPI's are key to winning a fight and can also be used to assist in the planning of training programmes. Future studies should look at whether the most recent change in the scoring criteria has had an effect on the performance demands of female

boxing. Also, looking into the performance demands of different weight classifications within female boxing would be beneficial in understanding the technical and tactical differences between weights.

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Appendix 1- Written Permission to use footage

Performance Analyst

Rebecca Edginton

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To whom it may concern,

On behalf of GB Boxing I am pleased to grant Sam Thomas permission to carry out research using footage provided by GB Boxing as part of his studies at the University of Chester. I am aware that this footage will be used to analyse the performances of the boxers.

It is my understanding that any data presented in Sam's research project will be fed back and available for use within our organisation.

Yours Sincerely

Rebecca Edginton

Senior Performance Analyst English Institute of Sport (GB Boxing)

Appendix 2- Ethical Approval

Faculty of Life Sciences

Research Ethics Committee

frec@chester.ac.uk

Samuel Thomas

Lintin Close

Bratton

Dear Samuel

Study title:	**An analysis of the technical performance demands of elite female boxers**
FREC reference:	**1094/15/ST/SES**
Version number:	***1***

Thank you for sending the amendments to your application to the Faculty of Life Sciences Research Ethics Committee for review.

I am pleased to confirm ethical approval for the above research, provided that you comply with the conditions set out in the attached document, and adhere to the processes described in your application form and supporting documentation.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Application Form	1	June 2015
Appendix 3 – List of References	1	June 2015
Appendix 4 – Summary CV for Lead Researcher	1	June 2015
Appendix 5 – Written permissions from relevant personnel	1	June 2015

Please note that this approval is given in accordance with the requirements of English law only. For research taking place wholly or partly within other jurisdictions (including Wales, Scotland and Northern Ireland), you should seek further advice from the Committee Chair / Secretary or the Research and Knowledge Transfer Office and may need additional approval from the appropriate agencies in the country (or countries) in which the research will take place.

With the Committee's best wishes for the success of this project.

Yours sincerely,

Dr. Stephen Fallows

Chair, Faculty Research Ethics Committee

Enclosures: Standard conditions of approval.

Cc. Supervisor/FREC Representative

Appendix 3- Table of definitions used.

Table 6. Definitions for KPI's.

Jab	A straight punch from the lead hand that moves along the sagittal plane (the central visual line) from anterior to posterior
Backhand	A straight punch from the rear hand that moves along the sagittal plane (the central visual line) from anterior to posterior
Lead Hook	A punch from the lead hand that moves along the transverse axis in a sideward 'sweeping' motion
Rear hook	A punch from the rear hand that moves along the transverse axis in a sideward 'sweeping' motion
Very Successful	A punch labelled very successful as it visibly lands on the opponent's target area, and has an instant negative effect upon them. The punch must land directly with the knuckle part of a closed glove or any part of the front or sides of the head or body above the belt line of the opponent.
Successful	A punch labelled successful as it visibly lands on the opponent's target area. The punch must land directly with the knuckle part of a closed glove or any part of the front or sides of the head or body above the belt line of the opponent.
Unsuccessful Hit	A punch labelled unsuccessful even though it makes contact with the opponents target area. It is deemed unsuccessful as poor contact is made with the opponent, and has no detrimental effect upon them.
Unsuccessful Defended	A punch labelled unsuccessful as it visibly doesn't land on the opponents target area, due to it being successfully defended by the opposing boxer.
Unsuccessful Miss	A punch labelled unsuccessful as it doesn't land on the opponents target area due to their personal doing. The exerted punch misses the target area due to their own ability and no other anomalies.
Arm Defence	Movement of both arms in order to block/parry the oncoming punch away from its intended target area.
Trunk Defence	Movement centred around the trunk in order to avoid a punch; the movement being either left or right, also known as slip left and slip right
Foot Defence	Movement whereby the boxer transports their centre of mass away from the attacker to avoid punches directed towards them. This is typically achieved via boxing-specific foot movement/steps.
Initiated Attack	Any punch or combination of punches initiated by a boxer and which the opponent also attacks. This indicator is a continuous event in that the duration of the attack is recorded.
Individual Attack	Any punch or combination of punches initiated by a boxer to which the opponent does not also attack . This indicator is a continuous event in that the duration of the attack is recorded.
Power Punches	The total number of backhands, lead hooks, rear hooks, lead uppercuts and rear uppercuts.
Efficiency	The total number of very successful and successful punches, divided by total number of punches.
Lead uppercut	A punch from the lead hand that moves along the sagittal plane and the longitudinal axis beginning with a downward projection and ending with an upward projection
Rear Uppercut	A punch from the rear hand that moves along the sagittal plane and the longitudinal axis beginning with a downward projection and ending with an upward projection

Appendix 4- Reliability Tables

Table 7. Intra-reliability for all performance indicators

Performance Indicator	Median (sign test P)	Percentiles 2.50%	Percentiles 97.50%	PA=0 (%)	Confidence Interval (%)	PA ± 1 (%)	Confidence Interval (%)
Total Punches	0 (0.375)	-0.725	1	58.3	30.4 to 86.2	100	100 to 100
Jab	0 (0.25)	-1	0	75	50.5 to 99.5	100	100 to 100
Backhand	0 (1)	-0.725	1	75	50.5 to 99.5	100	100 to 100
Leadhook	0 (1)	0	0.725	91.7	76.0 to 100	100	100 to 100
Rearhook	0 (1)	-0.725	0.725	83.3	62.2 to 100	100	100 to 100
Very successful	0 (1)	-0.725	0	91.7	76.0 to 100	100	100 to 100
Successful	0 (1)	0	2	75	50.5 to 99.5	83.3	62.2 to 100
Unsuccessful Hit	0 (1)	-1.725	1	58.3	30.4 to 86.2	91.7	76.0 to 100
Unsuccessful Defended	0 (0.125)	-2.45	0	66.7	40.0 to 93.4	91.7	76.0 to 100
Unsuccessful Miss	0 (1)	-1.725	1.725	50	21.7 to 78.3	83.3	62.2 to 100
Defended Foot	0 (1)	-0.725	1	75	50.5 to 99.5	100	100 to 100
Defended Trunk	0 (0.375)	-1	0.725	58.3	30.4 to 86.2	100	100 to 100
Defended Arm	0 (1)	-1.725	0.725	75	50.5 to 99.5	91.7	76 to 100
Exchange Initiated	0 (1)	-0.725	0.725	83.3	62.2 to 100	100	100 to 100
Individual Attack	0 (0.063)	-1	0	58.3	30.4 to 86.2	100	100 to 100

Table 8. Inter-reliability for all performance indicator.

Performance Indicator	Median (sign test P)	Percentiles 2.50%	Percentiles 97.50%	PA=0 (%)	Confidence Interval (%)	PA ± 1 (%)	Confidence Interval (%)
Total Punches	0 (1)	-3	3.725	25	0.5 to 49.5	41.7	13.7 to 69.6
Jab	1.5 (0.549)	-1.725	3	8.3	0 to 24.0	41.7	13.7 to 69.7
Backhand	0 (1)	-2.725	2.725	33.3	6.7 to 60.0	66.7	40.0 to 93.3
Leadhook	0 (0.727)	-2	2.45	33.3	6.7 to 60.0	75	50.5 to 99.5
Rearhook	-0.5 (1)	-1.725	2	8.3	0 to 24.0	75	50.5 to 99.5
Very successful	0 (0.125	-1	0	66.7	40 to 93.3	100	100 to 100
Successful	0.5 (1)	-2.725	7.45	8.3	0 to 24.0	41.7	13.7 to 69.6
Unsuccessful Hit	0 (1)	-4.725	6.175	41.7	13.7 to 69.6	58.3	30.4 to 86.2
Unsuccessful Defended	-2 (0.065)	-6.725	2	8.3	0 to 24.0	8.3	0 to 24.0
Unsuccessful Miss	0 (1)	-4.45	3.45	33.3	6.7 to 60.0	33.3	6.7 to 60.0
Defended Foot	-0.5 (0.125)	-4	0.725	41.7	13.7 to 69.6	66.7	40 to 93.3
Defended Trunk	-0.5 (0.688)	-1	1	16.6	14.4 to 37.7	100	100 to 100
Defended Arm	0 (0.219)	-1.725	0.725	50	21.7 to 78.3	91.7	76.0 to 100
Exchange Initiated	0 (0.453)	-3.725	1	41.7	13.7 to 69.6	83.3	62.2 to 100
Individual Attack	0 (1)	0	0	100	100 to 100	100	100 to 100